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WASTES USE IN PRODUCTION

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TECHNOLOGY FOR PRODUCING MINERAL FIBERS BY RECYCLING ASH-SLUDGE AND OIL-SHALE WASTES

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The technology for recycling ash-sludge and oil shale wastes using an electro-plasma facility in the production of mineral fibers, for melting silicate-containing materials, and schemes for additionally heating the silicate melt stream at the exit from the melting furnace is described. Studies of the electro-plasma facility and raw materials as well as the mineral fibers obtained with their use have been performed.

Key words: waste recycling, electro-plasma facility, silicate melt, mineral fibers.

The problem of recycling technogenic wastes — a mineral residue containing 49 – 61% SiO_2 — is always topical. However, the high melting temperature is holding back the recycling of such wastes. At the present time a melt of silicate-containing energy-production wastes, which have a melting temperature of the order of 1600 – 1700°C, cannot be obtained because the temperatures attained by existing heating units are lower. Therefore, it is necessary to use the energy of low-temperature plasma with high energy density and temperature 3000 – 5000°C. In addition, with highly concentrated plasma flow less energy is used to obtain silicate melt because less time is needed to heat the melt.

The topicality of such studies confirms the fact that even though some success has been achieved wide adoption of plasma technologies in the production of heat-insulating materials has been held back by a lack of both the theoretical and technological prerequisites for developing specialized high-capacity equipment and informative data on the electro- and thermophysical characteristics of obtaining silicate melt.

The objective of the present work is to develop a technology for producing high-temperature silicate melts from ash-sludge and oil shale wastes for manufacturing mineral fiber using a low-temperature plasma facility.

The production of slag cotton consists of two successive processes: melting the initial material in appropriate melting furnaces to produce melt with the required temperature and immediate processing of the melt into fiber [1].

The melt obtained in melting furnaces must possess the required physical properties: flowability, dynamic viscosity, and surface tension [2].

The use of high-enthalpy plasma flows makes it possible to reduce to a minimum the time from the formation of homogeneous melt to fiber formation. In actuality, the melting processes are combined with fiber formation, so that the melt temperature is high at the moment a fiber is formed, making it possible to melt mix with a high acidity modulus M_a. The rates of the physical-chemical processes depend on the particle-size composition of the mix components, the uniformity of the mechanical mixture, the chemical composition, and in consequence a number of thermophysical factors — melting time, melt output temperature at the tap, viscosity, surface tension, diffusion, and melt homogeneity.

As a first step in this work the melting temperature of the initial materials was determined using the phase diagram of the system $CaO – Al_2O_3 – SiO_2$. The changes occurring in the amount of the liquid phase in the initial materials with increasing temperature can be followed from the melting curve in Fig. 1.

Analysis of the melting curves obtained showed that a melt of the experimental initial material starts to form at temperature 1350°C, while a basalt melt starts to form at 175°C lower. A 100% melt of ash and oil shale wastes, required to obtain high-quality mineral fibers, forms in the range

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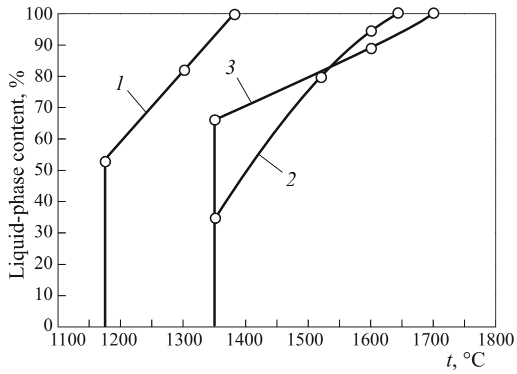

Fig. 1. The liquid-phase content during melting of materials versus temperature: *1*) basalt; *2*) ash; *3*) wastes from oil shales.

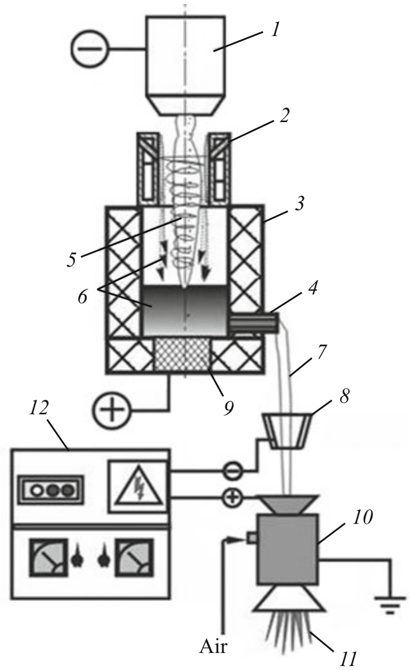

Fig. 2. Diagram of additional heating of silicate melt and mineral-fiber production: *1*) cathode unit; *2*) heat concentrator; *3*) melting furnace; *4*) tap; *5*) plasma arc; *6*) melt; *7*) melt stream; *8*) guiding funnel; *9*) graphite anode; *10*) melt blowing apparatus; *11*) mineral fibers; *12*) dc current source.

1600 – 1700°C. The most refractory wastes are oil shale wastes, whose melting temperature is 1700°C.

It is well known that the melt stream cools as it flows out of the melting-furnace tap and, correspondingly, the viscosity of the melt changes and fiber quality decreases. This led to the development of a facility that makes it possible to heat locally the melt stream flowing out of the tap by passing an electric current along the stream.

An electro-plasma facility was developed to obtain melt from the components indicated above [3]. During operation the melt temperature decreases sharply at the exit from the melting furnace, which impedes the formation of fibers with

TABLE 1. Temperature in the Melt Stream as a Function of the Electric Power at the Exit from the Melting Furnace

Experiment No.	Current strength I, A	Voltage U, V	Power P, kW	Melt temperature in stream t, °C
0	–	–	–	1650*
1	45	160	7.2	1670
2	60	145	8.7	1720
3	75	140	10.5	1750
4	120	130	15.6	1790

* Melt temperature at the tap exit of the melting furnace.

the required characteristics. To solve this problem a system that additionally heats the melt stream flowing out of the melting furnace was developed (Fig. 2). This system includes the following: cathode unit *1*, melting furnace *3*, guiding funnel *8*, facility for blowing the melt into fibers *10*, and dc power supply *12*. The funnel *8*, consisting of an electrically conducting material, possesses inner and outer walls, the annular cavity between which serves to feed cooling water and is secured beneath the tap *4*, built into the side wall of the furnace *3*. The current in-leads of the regulatable dc power supply *12* are connected to the funnel *8* and the blowing apparatus *10*, which allows current to flow along the section of the melt stream between these elements because the melted initial material is electrically conducting.

This scheme makes it possible to additionally heat the melt, in order to impart the required viscosity, by changing the strength of the current flowing in the stream. In addition, there is no need to reheat the melt in the melting furnace to temperature much above the working value.

The experimental results on heating the melt stream at the exit from the melting furnace are presented in Table 1.

Therefore, it can be concluded that the power of the low-temperature plasma generator is adequate for obtaining 100% melt of the initial material in a short time. The scheme developed for additionally heating the silicate melt stream at the exit from the plasma reactor by passing electric current through the steam makes it possible to affect in real-time the value of the temperature and viscosity of the melted material and therefore the quality of the final product.

Differential-thermal analysis of the mineral fibers obtained from basalt and technogenic wastes (ash from central heat-and-electricity plants, oil shale wastes) was performed to determine the limit at which the fiber materials retain their properties when exposed to high temperatures and to determine the characteristic temperatures of the crystallization process. The results are presented in Fig. 3.

The DTA curves of all fibers possess exothermal peaks attesting to the appearance of crystalline phases. The maxima of these peaks correspond to temperature 610°C for basaltic fibers and 765 and 790°C for fibers made from ash and oil shale wastes, respectively, for which crystallization occurs especially rapidly.

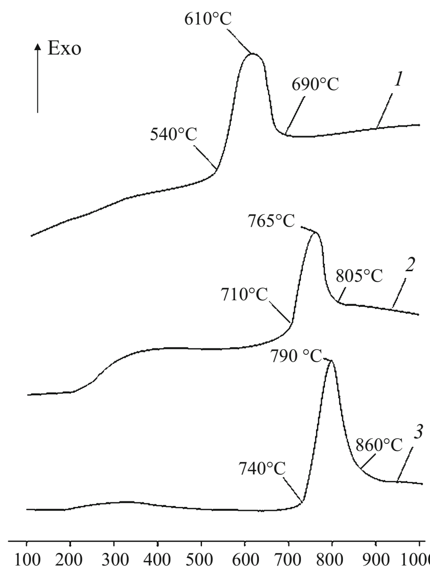

Fig. 3. DTA curves for mineral fibers obtained from basalt (*1*), ash (*2*), and oil shale wastes (*3*).

It was determined that the elasticity and strength of basaltic fiber decrease above 610°C. Therefore, basaltic fiber obtained by the plasma method can be used to 610°C. Analysis of the DTA curves for ash fiber and fibers obtained from oil shale wastes showed that such fibers begin to break down at 710 and 740°C, respectively. Therefore, the fibers obtained from oil shale melt are most resistant to high temperatures.

In summary, the present studies of wastes, obtained from energy production, with different chemical and mineralogical composition have established that such wastes can be used in the production of mineral fibers. Ashes and oil shale wastes, which possess a high acidity modulus, can be used to produce fibers with high chemical stability and operating properties, provided that the melt obtained is homogeneous and chemically highly uniform, which plasma technology and additional heating of the silicate melt stream make possible.

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